# Chapter 2. Salt Management Using IFDM

## I. Introduction

Farming in high saline areas limits farmers' options on how they manage the accumulation of salt on productive farmland. The options are variable and depend on the physical conditions within the farm boundaries and the farm economics.

The key to any drainage management program is improved irrigation efficiency. The more efficient the irrigation, the less volume of drainage water to manage.

Land retirement, drainage water reuse and the sequential use of drainage water are a few of the major options available.

Efficient irrigation is the first step in establishing a successful IFDM system.

## II. Land Retirement

As a result of decisions on recent litigation and for lands that are severely impacted by a high water table, land retirement is a land management option. Land retirement is the permanent removal of farmland from crop production.

However, there are some concerns about retiring historically productive agricultural land. These concerns include: reduced tax funds to the local government; the cost of managing previously privately owned land will become the responsibility of the Federal, State, and local governments; reduced land management may negatively affect selenium levels, and the economic impact on small communities.

Research funded by the U. S. Bureau of Reclamation is underway to evaluate whether or not land retirement will benefit wildlife.

## III. Drainage Water Reuse

### A. Single Reuse

Subsurface drainage water is used a single time to irrigate salt-tolerant crops and forages.

### B. Cyclic Use

Cyclic use is applying irrigation water of appropriate quality according to plant growth stage. Salt-tolerance varies throughout the growing season in most crops.

For example, use of higher quality irrigation water is necessary during germination and stand establishment. Then, as the crop matures, lower quality irrigation water can be used.

### C. Blending

Blending is a method of drainage water reuse. With this technique, crops are irrigated with a mixture of irrigation water and drainage water. More salt-sensitive crops can be grown using this technique than with single reuse.

### D. Sequential Reuse

In sequential reuse, the drainage water is collected and applied to crops with an increasing degree of salt tolerance. The sequential use of drainage water is, in fact, an incomplete or partial IFDM system.

While IFDM embraces the same practice, the final stage of an IFDM system uses a solar evaporator to "process" the final stage of the drainage water, producing potentially marketable salts.

The development of the solar evaporator for the final step in the salt management system is the difference between sequential reuse and a complete IFDM system, as described in the Solar Evaporator Regulations under Draft Title 27 §22910:

*"Integrated on-farm drainage management system" means a facility for the on-farm management of drainage water that does all of the following:*

1. *Reduces levels of salt and selenium in soil by the application of irrigation water to agricultural fields.*
2. *Collects agricultural drainage water from irrigated fields and sequentially reuses that water to irrigate successive crops until the volume of residual drainage water is substantially decreased and its salt content significantly increased.*
3. *Discharges the residual agricultural drainage water to an on-farm solar evaporator for evaporation and appropriate salt management.*
4. *Eliminates discharge of agricultural drainage water outside the boundaries of the property or properties that produces the agricultural drainage water and that is served by the integrated on-farm drainage management system and the solar evaporator.*

See Chapter 5 for more information on single reuse, cyclic use, blending and sequential reuse, including IFDM.

# IV. What is an IFDM System and How Does It Work?

An IFDM system uses high quality irrigation water on salt-sensitive, high-value crops (Stage 1). Then subsurface drainage water is sequentially reused to irrigate plants of increasing salt tolerance (Stages 2, 3, and 4). After irrigation with fresh water in Stage 1, the subsurface drainage water is collected from the field and it is blended with fresh water and/or tailwater, for use in Stage 2. In Stage 3, forage grasses and/or halophytes are irrigated solely with subsurface drainage water coming from Stage 2. In a three–stage system, drain water from Stage 3 is concentrated and evaporated in a solar evaporator, leaving dry salt as a product, which may be marketed, stored, or disposed. In a four–stage system, halophytes are irrigated with water from Stage 3, then the drain water from Stage 4 is concentrated and evaporated in a solar evaporator, leaving dry salt as a product, which may be marketed, stored, or disposed. Figure 1 is a schematic of three–stage and four–stage sequential water reuse.

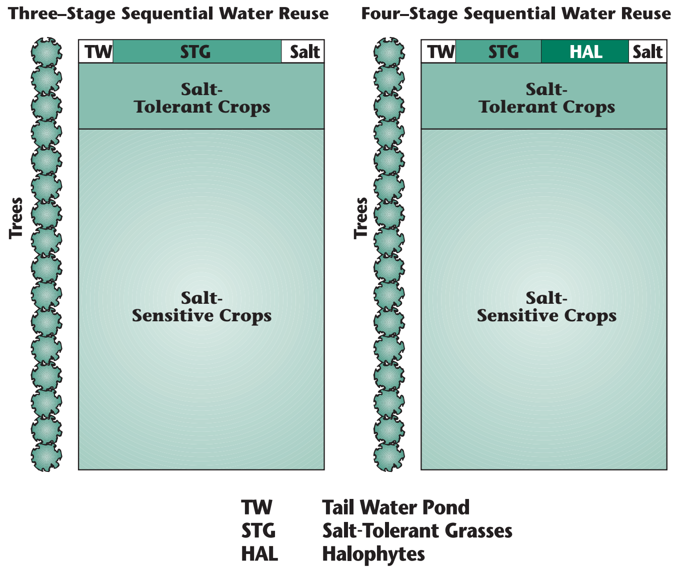



Figure 1. Multiple stage sequential water reuse.

Figure 2 shows the IFDM system at AndrewsAg (southern Kern County), which began in 1999 and consists of three–stages (drainage water reused twice). Figure 3 shows the IFDM system at Red Rock Ranch (Five Points, CA) which began in 1995 and consists of four–stages (drainage water reused three times).

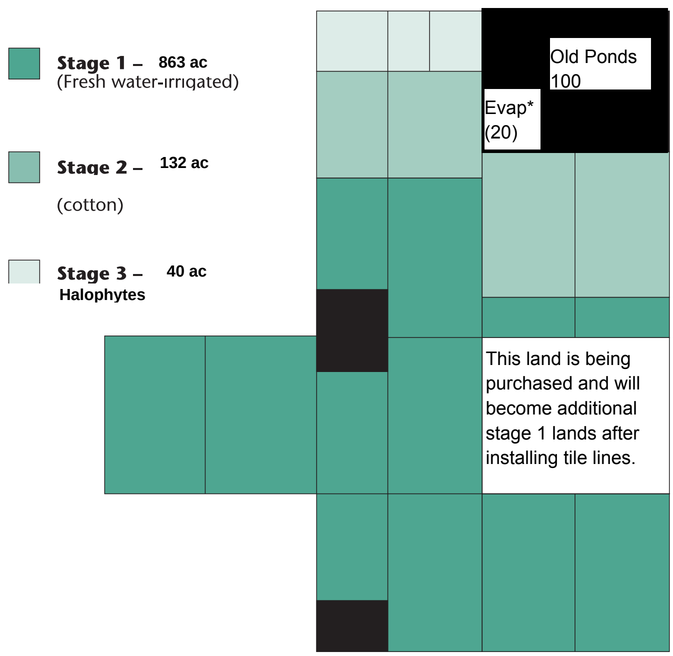



Figure 2. AndrewsAg IFDM. Sequential reuse, 3 stages (1035 acres).

*Evap = solar evaporator (20 A), 10 may have been sufficient

# V. Components of an IFDM System

The system may consist of border strips of trees to intercept regional groundwater flow, three distinct crop production areas, each with its own subsurface drainage system and sump, sump pumps and piping to move the collected subsurface drainage water to each of the cropping areas, and a solar evaporator.

## A. Border Strips of Trees

Border strips of trees are useful when subsurface lateral flow is a problem within ten feet of the surface. Benefits the tree strips offer include:

- Serve as a windbreak;
- Use large amounts of shallow groundwater, acting as biological pumps; and
- Lower water table.

Rows of trees are located upstream hydrologically of the IFDM system. Trees also are useful along crop areas where shallow groundwater problems arise. Eucalyptus, Athel and Casuarina trees are selected for their ability to use large volumes of water, and for their frost and salt tolerance (survive with water with TDS of 8,000-10,000 ppm).

## B. Crop Production Areas

The crop production area begins with Stage 1 where irrigation water is used for the production of salt-sensitive, high-value crops. Stages 2, 3 and 4 use different ratios of tail, drainage and fresh water to produce increasingly salt-tolerant crops.

**Stage 1** is the largest portion of the IFDM system. A well-designed subsurface drainage system provides the drainage necessary for the rapid leaching of salts brought in with the irrigation water. After one to three years, Stage 1 should be suitable for producing high-value salt-sensitive crops, which provide maximum economic return. Crop examples in rotation include a variety of vegetables.

**Stage 2** is the second largest portion of the IFDM system and is the first step in using drainage water. Salt-tolerant crops are irrigated with the

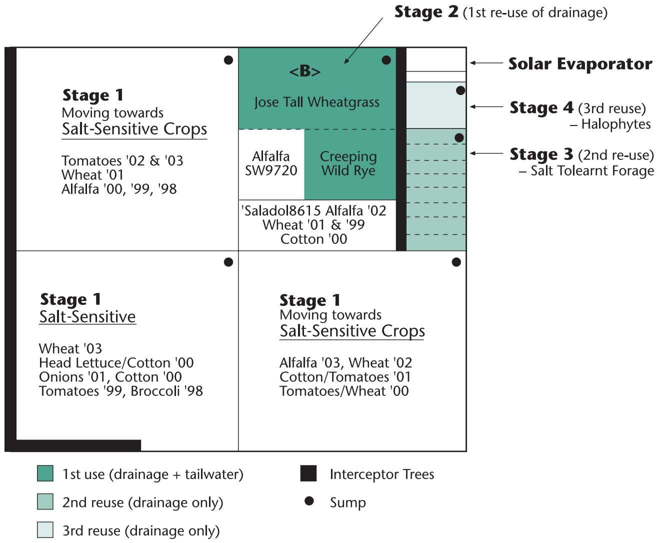



Figure 3. Red Rock Ranch IFDM. Sequential reuse, 4 stages (640 acres).

subsurface drainage water from Stage 1 that is blended with tail or irrigation water. Crop examples include cotton, tomatoes, sugar beets, canola and alfalfa.

**Stage 3** is the smallest crop production area of the IFDM system and is the second step in reducing the volume of drainage water. Salt-tolerant crops are irrigated with the subsurface drainage water from Stage 2. Crops are limited to salt-tolerant forage grasses or halophytes. If the salinity of the drainage water to be applied is less than 15 dS/m, the forage grasses would be recommended.

**Stage 4** could be included to further reduce the volume of drainage water and would be irrigated with subsurface drainage water from Stage 3. Stage 4 would only be planted with halophytes, plants that tolerate extreme salinity (applied water above 15 dS/m).

## C. Subsurface Drainage System

The purpose of a subsurface drainage system is to:

- Provide control of water table for farmer;
- Improve salt leaching.

The spacing, depth and number of drains in the IFDM system are influenced by soil type and economics.

Eucalyptus trees are useful for border strips where subsurface lateral flow is a problem.

# VI. Solar Evaporator

The purpose of the solar evaporator is to evaporate water in an acceptable manner.

Draft Title 27 §22920 of the Solar Evaporator Regulations states:

*Solar evaporators shall be designed by a registered civil or agricultural engineer, or a registered geologist or certified engineering geologist.*

The following definitions are from the Solar Evaporator Regulations under Draft Title 27:

(Draft Title 27 §22910 of the Solar Evaporator Regulations)

*"Solar evaporator" means an on-farm area of land and its associated equipment that meets all of the following conditions:*

1. *It is designed and operated to manage agricultural drainage water discharged from the IFDM system.*
2. *The area of the land that makes up the solar evaporator is equal to, or less than, 2 percent of the area of the land that is managed by the IFDM system.*
3. *Agricultural drainage water from the IFDM system is discharged to the solar evaporator by timed sprinklers or other equipment that allows the discharge rate to be set and adjusted as necessary to avoid standing water within the solar evaporator or, if a water catchment basin is part of the solar evaporator, within that portion of the solar evaporator that is outside the basin.*
4. *The combination of the rate of discharge of agricultural drainage water to the solar evaporator and subsurface drainage under the solar evaporator provides adequate assurance that constituents in the agricultural drainage water will not migrate from the solar evaporator into the vadose zone or waters of the state in concentrations that pollute or threaten to pollute the waters of the state.*

*"Standing water" means water occurring under all of the following conditions:*

1. *to a depth greater than one centimeter,*
2. *for a continuous duration in excess of 48 hours,*
3. *as a body of any areal extent, not an average depth, and*
4. *under reasonably foreseeable operating conditions.*

*"Water catchment basin" means an area within the boundaries of a solar evaporator that is designated to receive and hold any water that might otherwise be standing water within the solar evaporator. The entire area of a water catchment basin shall be permanently and continuously covered with netting, or otherwise designed, constructed, and operated to prevent access by avian wildlife to standing water within the basin. A water catchment basin may include an enclosed solar still, greenhouse or other fully contained drainage storage unit. For the purposes of this definition, the term "within the boundaries of a solar evaporator" shall include a solar still, greenhouse, or other fully contained drainage storage unit adjacent to or near the portion of the solar evaporator that is outside the catchment basin.*

The definition of water catchment basin includes an "enclosed solar still, greenhouse or other fully contained drainage storage unit."

Solar stills and greenhouses are enclosed structures that increase ambient temperature through solar radiation, causing an increase in evaporation.

One difference between them is that a solar still is a modified greenhouse that is used not only to increase evaporation, but also to separate salt and generate distilled water.

Research has been done with a solar still as a component of an IFDM system. It determined that a large area is required, and that it would be most appropriate for a large-scale operation. It is not commercially feasible on a small farm.

**Red Rock Ranch solar evaporation drainage water system.**

(Draft Title 27 §22910(l) of the Solar Evaporator Regulations)

*"Reasonably foreseeable operating conditions" means:*

1. *Within the range of the design discharge capacity of the IFDM system and the authorized solar evaporator system as specified in the Notice of Plan Compliance and Notice of Authority to Operate (§25209.13 of Article 9.7 of the Health and Safety Code);*
2. *Precipitation up to and including the local 25-year, 24-hour storm; and*
3. *Floods with a 100-year return period.*

*Operation of a solar evaporator in exceedance of design specifications is not covered by "reasonably foreseeable operating conditions," and therefore would constitute a violation of the Notice of Authority to Operate.*

(Draft Title 27 §22920 of the Solar Evaporator Regulations)

*A water catchment basin may be required:*

1. *As a component of a solar evaporator if standing water would otherwise occur within the solar evaporator under reasonably foreseeable operating conditions, or*
2. *If a solar evaporator is constructed with a liner. In this case, a water catchment basin shall be designed with the capacity to contain the maximum volume of water that the solar evaporator would collect under reasonably foreseeable operating conditions. A water catchment basin is not required for a solar evaporator that does not have a liner, if it is demonstrated that standing water will not occur under reasonably foreseeable operating conditions.*

## A. Salt Management

(Draft Title 27 §22940 of the Solar Evaporator Regulations)

*Salt Management — For solar evaporators in continuous operation under a Notice of Authority to Operate issued by a Regional Water Quality Control Board, evaporite salt accumulated in the solar evaporator shall be collected and removed from the solar evaporator if and when the accumulation is sufficient to interfere with the effectiveness of the operation standards of the solar evaporator as specified in this section. One of the following three requirements shall be selected and implemented by the owner or operator:*

1. *Evaporite salt accumulated in the solar evaporator may be harvested and removed from the solar evaporator and sold or utilized for commercial, industrial, or other beneficial purposes.*
2. *Evaporite salt accumulated in the solar evaporator may be stored for a period of one-year, renewable subject to an annual inspection, in a fully contained storage unit inaccessible to wind, water, and wildlife, until sold, utilized in a beneficial manner, or disposed in accordance with (3).*
3. *Evaporite salt accumulated in the solar evaporator may be collected and removed from the solar evaporator, and disposed permanently as a waste in a facility authorized to accept such waste in compliance with the requirements of Titles 22, 23, 27 and future amendments of the CCR, or Division 30 (commencing with Section 40000) of the Public Resources Code.*

# VII. Site Evaluation & Considerations

Once a farmer has been informed on what an IFDM system is, he can move forward to the project design and implementation. During the design phase, it is important to understand that a consultation with a qualified professional, such as a civil engineer, is neccessary for the individual site evaluation. A site evaluation should include climatology, groundwater, soil, farm area and subsurface drainage system.

Table 1. An example of monthly weather data available from CIMIS

| Date | ETo in. | PRECIP in. |
|---|---|---|
| MAR 00 | 4.34 | 1.18 |
| APR 00 | 6.34 | 0.87 |
| MAY 00 | 8.56 | 0.00 |
| JUN 00 | 8.75 | 0.04 |
| JUL 00 | 8.62 | 0.00 |
| AUG 00 | 7.95 | 0.04 |
| SEP 00 | 6.04 | 0.00 |
| OCT 00 | 3.87 | 1.81 |
| NOV 00 | 1.72 | -- |
| DEC 00 | 1.15 | 0.00 |
| JAN 01 | 1.59 | 0.33 |
| FEB 01 | 2.08 | 0.95 |
| ----TOTAL AND AVERAGES | | |
| | 61.02 | 5.22 |

# VIII. Climatology

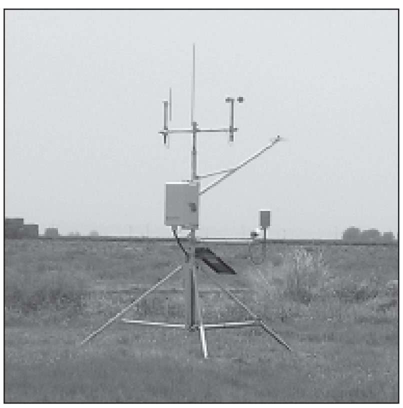
Review the historical and the most recent rainfall and other climatic data. An example of climatic data is presented in Table 1.

In areas with known flood potential, the designer will need to obtain data on flood occurrence from government agencies.

# IX. Groundwater

In working with groundwater, there are four main issues that must be studied:

- Groundwater quality;
- Groundwater quantity;
- Regional groundwater flow; and
- Water table depth.



A typical CIMIS-type weather station is necessary to monitor conditions that may impact IFDM systems.

There is some seasonal fluctuation in each of these, so it is important to make sure that the evaluation period covers all seasons.

Groundwater Quality: Constituents generally tested include:

- Salinity measured in (EC) or (TDS)
- Calcium
- Boron
- Molybdenum
- Sodium
- Magnesium
- Chloride
- Arsenic
- Sulfate
- Selenium
- Nitrate
- pH

It is important to use the correct sampling procedures and to send samples and control samples to qualified (ELAP certified) labs (see Chapter 3). The Regional Water Quality Control Board will specify the protocol for sampling.

The information collected from this initial water sampling is baseline data. This information will be compared with future data in order to monitor the IFDM system performance and management. (See Chapter 3 for more details on water quality monitoring information.)

# X. Regional Groundwater Flow

Shallow groundwater is made up of regional groundwater and deep percolation from inefficient irrigation. In general, the direction of the natural regional flow of groundwater is downslope from the Coastal Range on the Westside of the Valley, and flows northeast to the trough of the Valley.

The USDA's Natural Resources Conservation Service has used observation wells (piezometers) and/or backhoe pits placed throughout fields, for charting water tables and assessing the magnitude of regional flow over time. The evaluation time varies with the complexity of the hydrology of the area.

A grid must first be established to determine the placement of monitoring wells (observing points). This grid is determined after evaluating available soils data and the agronomic experience of the farmer. Grower input is important in identifying problem areas on the site. Monthly observations should be recorded for a full year to account for seasonal groundwater fluctuations.

The collected data are used to locate drains at an optimum depth in order to minimize the volume of drainage water. Drain depth is important because if it is too shallow, it is not effective and if it is too deep, the drain would collect larger volumes of regional groundwater.

Some regional groundwater flow data is available from water districts, including Westlands, (groundwater observation well logs) and the Department of Water Resources.

- **EM-31 and EM-38** may be useful for the initial site evaluation (to gather baseline data) and later as a tool to evaluate changes.
- **EM-31** is an electromagnetic probe that logs information on the presence of water down to 10′ as well as the location by GPS coordinates, so that accurate maps of groundwater may be created.
- **EM-38** is an electromagnetic probe that logs information (in varying increments) on salinity down to 4′ as well as the location by GPS coordinates, so that accurate maps of salinity may be created.

# XI. Soil

Soil survey: There are several soil resources that are available to landowners. The USDA Natural Resources Conservation Service (NRCS) has done extensive work on the characterization of the soils in the San Joaquin Valley, but it is essential that a site-specific soil survey be performed.
The steps are:

1. Create a grid: select, identify and map sampling sites, paying particular attention to intercept high EC areas.
2. Determine appropriate depth for sampling, based on the size of crop root zone (generally 5′).
3. Collect soil samples from selected sites. Send the samples to a certified laboratory that will analyze the soil and test for various constituents.

Clay soils pictured here are found at AndrewsAg in southern Kern County.

Backhoe pits may be utilized to study and characterize the soil profile.

Salinity survey: Salinity is usually one of the constituents evaluated in the soil survey report. Salinity data is useful in determining initial crop selection and leaching requirements.

Aerial photographs: 24,000 scale or 8″ to mile are helpful in identifying buried stream channels, high salt areas, and portions of the field that will require more intensive management. Infrared aerial photos are useful in identifying chronic salinity hot spots.

The data collected from the soil and salinity surveys will be used to design the IFDM system. It is to a farmer’s benefit to collect as much background data as possible. A current on-site investigation including traditional soil analysis and salinity analysis will help assess the current conditions, and may be helpful for future reference and comparison. Historical and current background data is available from the NRCS and aerial photographs (both new and historical) are available at CSU, Fresno, NRCS or DWR.

# XII. Farm Area

A detailed evaluation of the initial conditions of the site is the first step required for planning an IFDM design. Each of the following items has some impact on the design of the IFDM system:

## A. Acreage

Determine how many acres will be devoted to each of the sections of the IFDM system based on your cropping system, the subsurface drainage volume and quality of subsurface drainage water. The subsurface drainage volume will be directly affected by irrigation water management.

## B. Geography

Surveys and maps provide good information on location of stream beds (conduct underground water), and alluvial fans (slope and gradient vary and affect surface and subsurface flow which normally flows from southwest to northeast).

- Study historical cropping data from the past 5-7 (or more) years.
- Study the rainfall and climatic conditions (determine 24-hour rainfall) as well as flood occurrence (history of overland flow from flood occurrence). This information is available at local NRCS field offices.

## C. Slope

Slope and ground elevation are evaluated in the initial site survey. The information collected from the survey is utilized to prepare a topographic map of the site, which is helpful in the design of the irrigation and subsurface drainage systems, the placement of trees, and location of solar evaporator.

## D. Existing Systems and Infrastructure

Identify the location of farm water conveyance systems (canals, ditches, ponds, basins and collector sumps) as well as those located upslope of the site. Surface water conveyance systems have the potential to dilute the concentration of salt in the drainage water. Map out the site boundaries and locate field roads. Contact Underground Service Alert (USA) www.usanorth.org or (800) 227-2600, at least 2 working days before performing underground improvements, to find out the locations of underground utilities.

## E. Information for Siting the Salt Harvest Area

Evaluate elevation and slope, hydraulic conductivity of the soil, and measure groundwater and water table levels over a period of one year (especially during the rainfall period) to record fluctuation. This data is essential in determining what area will be most suitable for the salt harvest facility. It is very important that the solar evaporator be sited away from tail water reservoirs, ditches, and areas with a potential flood hazard. Berms and levees should be used where necessary in order to avoid potential problems with flooding and storm water.

# XIII. Subsurface Drainage System

The purpose of a subsurface drainage system is to provide control of the water table for farmers and to improve salt leaching. The drainage system should be designed by a qualified individual. The regulations state the solar evaporator must be designed by a registered civil or agricultural engineer or a registered geologist or certified engineering geologist.

Each of the crop areas requires an independent subsurface drainage system, sump and sump pump, as does the solar evaporator.

When designing the drainage water surface transport system, the qualified professional should account for the irrigation system efficiency and management, incoming water quality and leaching requirement.

# XIV. Water Management & Monitoring

## A. Water Pumping and Distribution in Crop Areas

Each pump must have a flow meter to monitor the amount of irrigation water applied. Each field must also have a sump into which the subsurface drainage system drains, a sump pump, and flow meter in order to keep track of the volume of water produced by the subsurface drainage system.

The quality of the subsurface drainage water and tail water collected from the sumps of Stage 1's salt-sensitive crops is monitored and mixed with fresh or tail water to make irrigation water of a specific EC to be applied to salt-tolerant crops in Stage 2. Thus, the salinity of Stage 2 is maintained within very close tolerances. Monitoring of water quality and measurement of the volume of water pumped allows for adjustments if there is a change in operation or water availability. This information can be used to improve water management.

## B. Flow Control in the Subsurface Drainage System

Flow control is desirable in a subsurface drainage system because it allows groundwater levels to be managed throughout the growing season to allow crops to utilize higher EC water.

In addition, it allows the grower to store drainage water in the soil during low evapotranspiration months. Flow control structures may be installed into an existing subsurface drainage system. Existing systems will require modification to deliver drainage water to the solar evaporator.

The agricultural engineer who designs the system should discuss with the farmer where to place the flow controls in the IFDM system for maximum benefit.

## C. Solar Evaporator

The objective of the solar evaporator is to evaporate water in an acceptable manner.

### 1. Location

Do not locate a solar evaporator:

1. Near tail water ponds;
2. Near irrigation or tail water ditches; and
3. In lowest topographic area of farm (danger of flooding).

(Draft Title 27 §22920 of the Solar Evaporator Regulations)

*Flooding—A solar evaporator shall be located outside the 100-year floodplain, or shall be constructed with protective berms/levees sufficient to protect the solar evaporator from overflow and inundation by 100-year floodwaters, or shall be elevated above the maximum elevation of a 100-year flood.*

This drainage sump at Red Rock Ranch will be used to collect monitoring data.

**2. Surface preparation for solar evaporator and/ or salt concentrator**

The prevention of the migration of salts from the solar evaporator into groundwater is done by proper surface preparation, and is addressed in the regulations (Draft Title 27 §22920 of the Solar Evaporator Regulations):

*Protection of Groundwater Quality — Solar evaporators shall be immediately underlain by at least 1 meter of soil with a hydraulic conductivity of not more than 1 x $10^{-6}$ cm/sec above the zone of shallow groundwater at any time during the year. The surface of the solar evaporator shall be a minimum of five-feet (5 ft.) above the highest anticipated elevation of underlying groundwater. A solar evaporator may be constructed on a site with soils that do not meet the above requirement, with subsurface drainage under or directly adjacent to the solar evaporator, a liner, or other engineered alternative, sufficient to provide assurance of the equivalent level of groundwater quality protection of the above soil requirement.*

### 3. Water Pumping and Distribution in Solar Evaporator

**a. Flood, Spray, and Sprinkler Systems may be used, but there are risks associated with each of them.**

- Flood systems must be intensively managed in order to avoid ponded water and potentially harming wildlife.

- The advantage of utilizing spray or sprinkler systems is that they allow water to be more equally distributed in the area of the solar evaporator.
- A risk of utilizing spray or sprinklers systems is drift.

Regardless of the system, it is critical **that there be a person designated and trained as the operator of the solar evaporator**. This person must be dedicated to supervising and managing the solar evaporator and avoiding conditions that could create wildlife hazards.

**b. Automatic System for Flood, Spray, or Sprinkler Systems**

- It is possible to have an automatic system for the solar evaporator that monitors the water level in the catchment areas and turns the pump on and off.
- Programming of the system must incorporate real time monitoring and CIMIS station data.
- By utilizing CIMIS data (from the station of closest proximity or from an on-site weather station), it is possible to program the system so the proper volume of water is pumped each day of the season.
- One method for decreasing the potential for water ponding is to limit the application rate to 70 percent of the ETo for the day or week.

**c. Monitoring Wells**

Monitoring wells will be required around the IFDM site, as prescribed by Draft Title 27 §22940 of the Solar Evaporator Regulations.

- The RWQCB sets the requirements for the number of wells to monitor the solar evaporator as well as what constituents water must be tested for.
- The RWQCB also sets the schedule for how often monitoring must be performed and the schedule for data and report submission.
- Monitoring is performed in order to show whether groundwater quality is affected by the use of the solar evaporator.

See Chapter 3 for more details on monitoring requirements.

**d. Design Options for Solar Evaporator**

The following are conceptual solar evaporation design options that are currently in the development stage.

It is essential that the qualified individual designing your solar evaporator determine what design option is most appropriate and effective for your individual farming operation.

One design option is a solar evaporator sloped toward the catchment basin, surrounded by levees (Figure 4).

The concentrated drainage water is applied by sprinklers to the surface of the solar evaporator. Some of the water evaporates and the remaining water becomes more concentrated and runs into the water catchment basin. The water catchment basin is a ditch that is covered by netting to prevent any access of wildlife to the water in the basin. This basin collects excess water during the rainy season and can be used for the temporary storage of drainage water. The water catchment basin must be designed to contain water generated from a 25-year/24-hour storm event. Both rain water and drainage water are pumped from this basin and applied to the surface of the solar evaporator.

It is possible that this type of solar evaporator could be subdivided into 2 or 3 sections or cells, and alternate use of sections or cells in order to allow complete evaporation and reduce insect

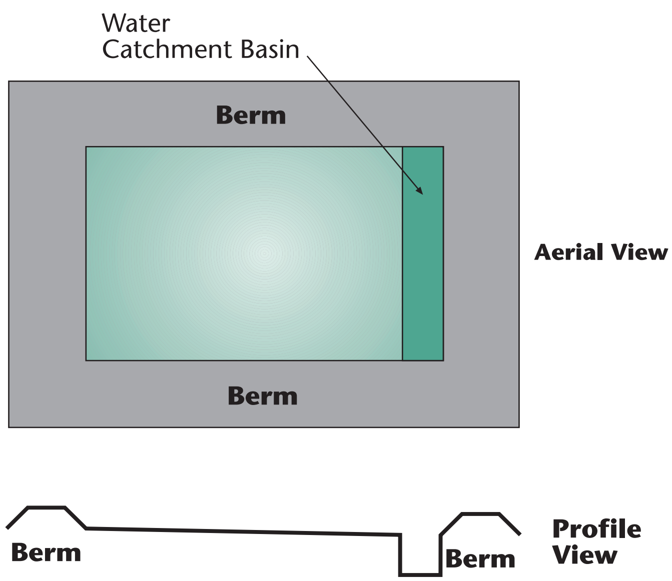



Figure 4. Solar evaporator and water catchment basin.

inhabitation. It is important to note that berms used to subdivide the solar evaporator into cells make the solar evaporator more attractive to nesting water birds. Avoiding the use of internal berms is a USFWS and CDFG best management practice recommendation to avoid impacts to nesting water birds.

Another design option is the combination of a solar evaporator with a salt concentrator, which would increase evaporation rates (Figure 5). Drainage water is applied to the sloped solar concentrator through specialized spray nozzles and recycled until the water reaches a specified concentration of salts. Then, the highly concentrated water is applied to the sloped solar evaporator to convert the salt to a dry crystallized form. The salt concentrator section would be covered with 2-1/2 to 3-inches of rock to increase evaporation time, as described above. This method could also be a multiple stage process of salt crystallization. A smaller salt harvest area would be the main advantage of this system that could also be used for the processing of marketable salt.

## e. Design Considerations

Typical average evaporation rates in the San Joaquin Valley area are about 82 inches per year. Evaporation rates are reduced as the salt concentration in the drainage water increases.

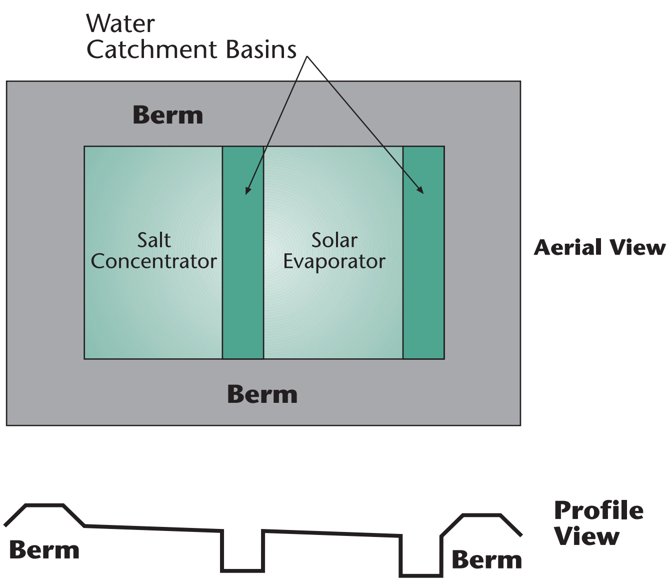



Figure 5. Solar evaporator with salt concentrator and water catchment basins.

Generally, the evaporation rate in a solar evap–orator is 70 percent of the typical evaporation rates (with an 82-inch evaporation rate, this would be about 58 inches). The estimated size of the solar evaporator for a given amount of processed drainage water is presented in Table 2.

Table 2. Estimated size of the solar evaporator.

| Volume of Drainage Water to be Processed (acre-feet) | Size of Solar Evaporator calculated acres x 1.25= | recommended acres |
|---|---|---|
| 6 | 1.3 | 1.6 |
| 8 | 1.7 | 2.1 |
| 10 | 2.1 | 2.6 |
| 12 | 2.5 | 3.2 |
| 14 | 2.9 | 3.7 |
| 16 | 3.4 | 4.2 |
| 18 | 3.8 | 4.7 |
| 20 | 4.2 | 5.3 |
| 22 | 4.6 | 5.8 |
| 24 | 5.1 | 6.3 |
| 26 | 5.5 | 6.8 |
| 28 | 5.9 | 7.4 |
| 30 | 6.3 | 7.9 |

Evaporation rates fluctuate during a year. The minimum levels are in the late fall, winter and early spring, and the maximum values are from late April to early October (Figure 6). The production of drainage water is greatest during the winter months, when evaporation rates are lowest. Since this pattern of water volume does not match the pattern of evaporation, consideration and planning of management options are necessary.

Options for addressing this problem include:

- Planning water application to decrease/ minimize the volume of water to be managed;
- A surface water storage facility (storage tanks); and
- If growing shallow rooted plants, storage of excess water in the soil profile below the root zone for later use (i.e., Dosier valves and/or sumps).

The water application rates to the solar evaporator must correlate with evaporation rates. A simple electronic timer can control these application rates. The daily application rates will fluctuate from 0.04 to 0.5 inches during the year.

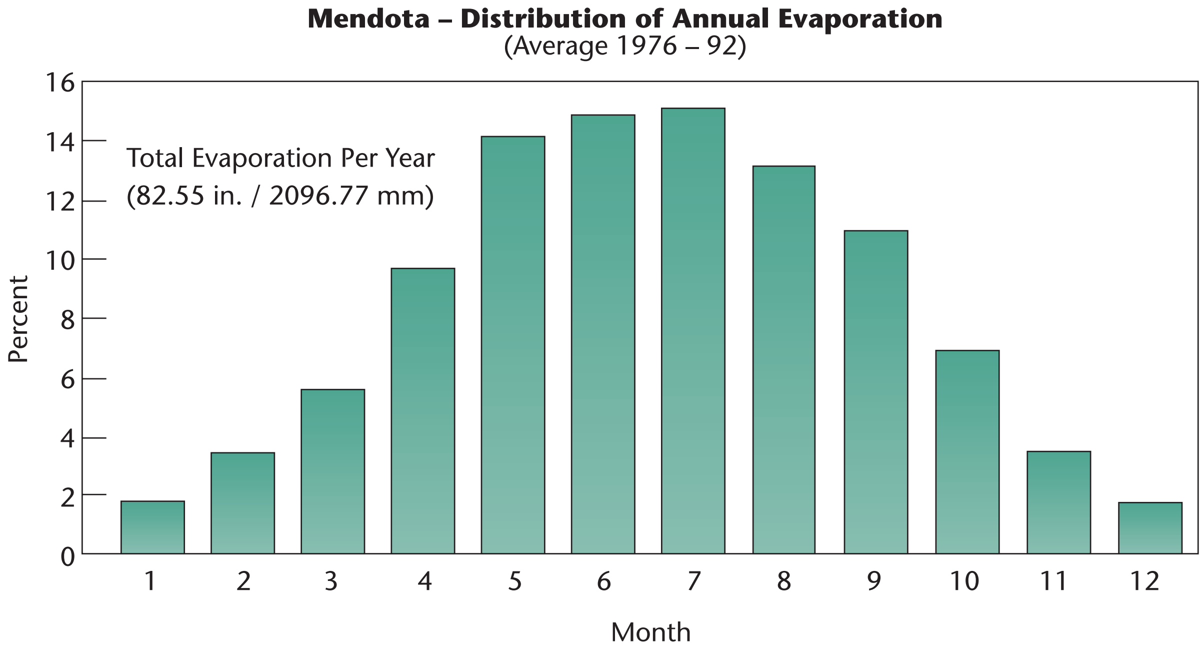



Figure 6. Evaporation rates throughout the year.

Table 3 gives the estimated time required to apply drainage water to the solar evaporator of a one-acre area, using a 250 gallons per minute pump.

The water catchment basin must be sized to accommodate the precipitation resulting from a local 25-year/24-hour storm. (See §22910(l), page 2-5).

Table 3. Water applied to solar evaporator (time required per day @ 250 gpm/acre).

| Water Evaporated Per Day (inch/day) | Water Volume Per Acre (gal/day) | Time of Pumping (minutes/day) |
|---|---|---|
| 0.04 | 1073.7 | 4.3 |
| 0.06 | 1610.6 | 6.4 |
| 0.8 | 2147.4 | 8.6 |
| 0.1 | 2684.3 | 10.7 |
| 0.15 | 4026.4 | 16.1 |
| 0.2 | 5368.6 | 21.5 |
| 0.25 | 6710.7 | 26.8 |
| 0.3 | 8052.8 | 32.2 |
| 0.35 | 9395.0 | 37.6 |
| 0.4 | 10,737.1 | 42.9 |
| 0.45 | 12,079.3 | 48.3 |
| 0.5 | 13,421.4 | 53.7 |

**Example of annual salt accumulation in solar evaporator**

One acre of solar evaporator can process nearly five acre-feet of water. At a salt concentration of 30,000 ppm (30 g/l), each acre-foot of water contains about 40 tons of salt. This would make about 200 tons of salt per one-acre area per year. This would create a layer of salt about 1.3 inches per year.

# XV. Crop & Tree Areas

## A. Water Reuse

Determine how many stages of water reuse are most appropriate for your farm.

- Three stage (Stage 1: salt sensitive, Stage 2: salt tolerant, Stage 3: very salt tolerant halophytes)
- Four stage (Stage 1: salt sensitive, Stage 2: salt tolerant, Stage 3: very salt tolerant, Stage 4: halophytes)

Considerations include cropping system, irrigation method, amount of subsurface drainage water produced and availability of irrigation water, tail water and fresh water.

## B. Irrigation Methods

Irrigation of each area of the farm varies:

- Stage 1: Drip, sprinklers, or furrow may be used. Determine what is most appropriate for crop and adequate leaching.
- Stage 2: Furrow or sprinklers. Sprinklers are better for optimal leaching and the prevention of ponding. Some salt-tolerant field crops or vegetables may be sensitive to sprinkling with saline water (due to foliar absorption). In this case, furrow may be necessary.
- Stage 3 and/or Stage 4: Sprinklers for halophytes. For salt-tolerant forages sprinklers may be used with lower salinity water and they allow quicker drying of the soil for forage cutting. If the salinity of the drainage water is near the limit for the forage, then surface irrigation would reduce the potential for damage from saline sprinkling.

## C. Establishment of Crops and Trees

The planting and establishment of trees and other perennials should be the first step in the implementation of an IFDM system. Trees should be irrigated with fresh water for at least the first year, in order to become established. Most crops, with the exception of halophytes, will also require fresh water irrigation for establishment. For perennial forages, this may also be a one-year period of time.

Location of Crops and Trees

- Location of trees depends upon direction and magnitude of regional flow.
- As mentioned before, trees are generally located along the appropriate boundaries in order to intercept regional subsurface groundwater flow.
- Avoid planting trees under power lines.
- Salt-sensitive crops are generally located on the IFDM fields with high elevations (keep in mind that there are pumping costs associated with elevation).

See Chapter 6 and the Appendix for more information on plant selection, culture, and management.

# XVI. System Operation & Maintenance

## A. Solar Evaporator

### 1. Monitoring

- Water table
- Groundwater quality
- Quantity of water pumped
- Maintain and monitor sprinkler distribution system
- Monitor application rate of water in solar evaporator

### 2. Wildlife

Avoid ponding water greater than 1 cm in depth for more than 48 hours to minimize impacts to avian wildlife (as required by Draft Title 27 §22940 regulations). If ponded water is avoided, many of the items listed below would not be an issue.

(Draft Title 27 §22940 of the Solar Evaporator Regulations)

*Avian Wildlife Protection — The solar evaporator shall be operated to ensure that avian wildlife is adequately protected as set forth in §22910 (a) and (v). The following Best Management Practices are required:*

1. *Solar evaporators (excluding water catchment basins) shall be kept free of all vegetation.*
2. *Grit-sized gravel (<5 mm in diameter) shall not be used as a surface substrate within the solar evaporator.*
3. *Netting or other physical barriers for excluding avian wildlife from water catchment basins shall not be allowed to sag into any standing water within the catchment basin.*
4. *The emergence and dispersal of aquatic and semi-aquatic macro invertebrates or aquatic plants outside of the boundary of the water catchment basin shall be prevented.*
5. *The emergence of the pupae of aquatic and semi-aquatic macro invertebrates from the water catchment basin onto the netting, for use as a pupation substrate, shall be prevented.*

To decrease the attractiveness of the area as a breeding site for birds, vegetation control around the solar evaporator is needed. Vegetation control

## B. Crops

### 1. New Salt-Tolerant Crops and Forage Crops

Possible crops being evaluated for salt tolerance include forage grasses, shrubs and flowers, such as statice and rose.

### 2. Halophytes with Commercial Value

Pickle weed has been grown successfully in some saline conditions. It is used as a food in several countries when irrigated with seawater (NaCl).

### 3. Flow-through System

The flow-through system that promotes biological activity with a hay bale carbon source has been used to reduce selenium levels in drainage water. Research into these systems is continuing with the goal of learning enough to make these systems more universally applicable.

### 4. Affect of Waterlogging on Soil Profile

Waterlogged soil is usually something to be avoided since, in waterlogged soil, water occupies all of the pore space in the soil, excluding air required for root respiration. Shallow groundwater can be an asset if it is deep enough in the soil profile. Some crops can use the water from shallow saline water tables to satisfy a portion of the crop's consumptive use. Storing drain water in the soil profile can mimic a naturally occurring, saline, shallow groundwater table. The ability to store water in the soil profile can provide additional flexibility in water management.

## C. Energy Alternatives

### 1. Solar Ponds

Solar ponds are deep bodies of saline water that develop a temperature gradient from top to bottom. This difference in temperature from top to bottom can be used to generate electricity. Successful installations existed in Texas and research ponds are planned for the Central Valley.

### 2. Saline Biomass Production for Energy Use

Biomass production is a proven technology. Growing plant material (both plants and trees) for energy production can be economically beneficial.

An example of tomatoes being grown on the Red Rock Ranch within the IFDM system.

should not be performed during the nesting season from February 1 through August 31 unless a qualified wildlife biologist has found the area to be nest-free.

Earthen berms or levees inside the perimeter of the solar evaporator are attractive to wildlife. (See the technical manual for information about alternatives to earthen levees.)

Hazing with propane canons, cracker shells and colored tape are some avoidance measures that may be effective in reducing migratory birds foraging and nesting in or around the solar evaporator during the early spring and summer months.

There should be a person designated and trained as the operator of the solar evaporator. This person must be dedicated to supervising and managing the solar evaporator and avoiding conditions that could create wildlife issues.

# XVII. Future Investigations

Research is underway to discover new uses and applications for salt as well as to refine IFDM processes. The research focuses on the following areas.

## A. Salt harvest Utilization and Marketing

Salt marketing is the preferred option for salt removal. Sodium sulfate is the main component of the salt produced by the salt harvest system in the San Joaquin Valley and is suitable for a variety of markets. Ninety-nine percent pure sodium sulfate has a market value of ~$50/ton. Commercial uses include the textile industry, ceramic and glass production and detergents. Salt consists of various combinations of sodium, calcium, sulfate, chloride, boron, magnesium, selenium and other elements, which are commercial commodities.

The Department of Water Resources has been working with the University of California, Davis, and several salt companies on the development of salt products and markets. The salt harvested from the farms in the San Joaquin Valley may have some economic value. Salt companies could benefit from a free source of salt and farmers could benefit from moving the salt out of the Valley. Salt production in the San Joaquin Valley also would be in relative proximity to main salt markets (Los Angeles Basin, Bakersfield, Fresno and the Bay Area) and to major ports (Stockton and Los Angeles Basin).

### 1. Recovery Purification and Utilization of Salts from Drainage Water

The key to producing a marketable salt product is a high degree of purity. Research is continuing on methods to produce and recover salts (of the necessary purity) in an economical manner.